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Reveal Difference in Synthetic Aperture Radar Images Implementing Fuzzy Clustering Along With Improved MRF Energy Function and Wavelet Denoising Technique

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Abstract

In this paper we put forward a novel method to reveal difference in synthetic aperture radar (SAR) images. In this approach we classify the changed and unchanged region by the help of the fuzzy c-means (FCM) clustering along with the use of an Improved Markov random field (MRF) as energy function. It is important to deal with speckle noise that is found in SAR images. So we use Improved MRF energy function along with FCM and a Wavelet denoising technique to reduce the speckle noise found in the SAR images. In this we use two methodologies for the detection of change in synthetic aperture radar (SAR) images. First, we apply the Wavelet Bayesian denoising technique to reduce the speckle noise. Then the image fusion technique is introduced to generate a difference image by using complementary information from a mean-ratio image and a log-ratio image. Later with the help of FCM and the improved MRF we detect the variation in the SAR images. The main advantage of the proposed method is its dominance in reducing speckle noises and its computational simplicity.

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Keywords:Fuzzy C-Means Clustering (FCM); Synthetic Aperture Radar (SAR) images; Log Ratio operator,;Mean Ratio operator; Markov Random Field (MRF);Wavelet Bayesian Denoising Technique.

1. INTRODUCTION

The detection of the variation in the same image taken in different time is of great interest due to its largeapplication in the current world. It's well said that the Earth's surface is in constant motion. Natural disasters like earthquakes, hurricanes, and volcanic eruptions often make big headlines. So it is very essential to detect the changes, so that we will be able to do our best in the time of the disaster and reach help to the people in the affected area. In this paper

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we put forward a method that helps us to respond to disasters around the world because of the efficient detection of changes in that area. To come out with quick help and support, makes an impact on the struggling community.

In this paper we use the synthetic aperture radar images. Synthetic-aperture radar (SAR) is a type of radar image which can be used to create images of objects, such as landscapes. In this paper we propose a method to find the difference between the two SAR images that has been taken in two different times. In this method we don't have any prior knowledge about the scene. This paper has a wide application in remote sensing, medical diagnosis, video surveillance and disaster management.

The main steps that are involved in distinguishing the variation in the SAR can be categorized into 3 steps. In the first stage we pre-process the image. Then we attain a difference image (DI) from the multi temporal images. Later we evaluate the DI that had been obtained. It is very important to deal with the speckle noise. If there is any scope of noise or error then it will affect the change detection in a negative way. But usually the SAR images are obtained in a degraded form. So the amount of speckle noise is very high.

As the SAR images are independent of the sunlight and atmospheric condition, so the rate of speckle noise is very high. To decrease the rate of speckle noise we first generate the DI of the two images, [13] by the help of the image fusion of the mean ratio image and log-ratio image. Alongside with the generation of DI we also use the procedure for image segmentation. Image segmentation can be done with the help of the two developed method, that is the threshold method and clustering method. In the threshold method we need to establish a model for finding the threshold for the classification of the images. But in the clustering technique we do not need to establish a model. So, by the help of the Fuzzy C-Mean [15] clustering we retain more image information. We also use the improved Markov Random Field as an energy function along with the FCM for the better results. To reduce the speckle noise found in the SAR images, we use the Wavelet denoising technique also.

The paper later explains about the literature survey in Section II. The Section III gives the descriptions of the methodology that is being used in the change detection of the SAR images. Finally we conclude with Section IV.

2. LITERATURE SURVEY

This paper proposes a novel method that detects the change of the synthetic radar image (SAR) before and after a time period. In this paper we habit the image fusion of the mean ratio image and log ratio image to find the Difference Image (DI). These DI can be found by the support of the image fusion of mean ratio image and the log ratio image for simplicity. There have being many methods found for the finding of the change in the synthetic radar image (SAR). Hidden Markov random field (HMRF) copies [3] are also broadly used for image segmentation, as they can be used in problems where a spatially reserved clustering scheme is used. Fuzzy *c*-means (FCM) clustering has also been effectively applied in some image segmentation applications. This can be used for locating excellent robustness. An HMRF model [3] is a stochastic process created by an MRF, in this state sequence can be conditional only through a random field of observations.

There are various systems for detecting the transformation revealing in the images by unsupervised distribution-free method [5]. In this the image fusion practice is used to create a variation in image by the aid of combined information from the mean-ratio image and a log-ratio image. There can be many variations that can be used for the FCM. Fuzzy Local Information C-Means (FLICM) is such a method. In this way [4] we incorporate the local spatial information and grey level information in a novel fuzzy way. The key feature of FLICM is the use of a fuzzy local (both spatial and grey level) likeness measure, which relief to reduce the noise then preserve the image detail.

There are many approaches to find the variation in image and various means for image clustering. Fuzzy c means is one such way used. In this paper we use the fuzzy c mean method for it gives high accuracy than the extra image clustering methods.This technique uses the information around the spatial setting in the fuzzy way for enhancing the altered information and decreasing the effect of speckle noise. Another different of the widely used Fuzzy C-Means (FCM) algorithm that supports clustering data circulated across different sections [6]. Some of the systems are named as combined and matching fuzzy clustering.

In this paper we familiarize a way called MRF energy function in the Fuzzy C-Means clustering algorithm to improve the robustness. It is a powerful tool that can be used for the implementation. The use of a pixel-level MRF [8] makes the clustering deficient to deal with images with enhanced texture patterns. But we can find many modified version of MRF energy function. Region level MRF is such an advanced method of Markov Random Field [8]. This method turns an important role in explaining large-range difference of macro textures. In this paper we consider the complexity of image features; a region-level mean template is also created to improve the relationships among the neighbouring regions. But this method has being verified as a better method than the four state-of-the-art competitors.

The other technique used for advanced FCM is applying spatial constraints [7][21] with the algorithm. But this method has its own control like it takes more time and the difficulty is very high. Image change detection is widely used in applications such as robot vision, object recognition, geographical imaging and medical imaging. So this method can be used as an application of change detection.

The change in multi temporal synthetic aperture radar images [2] can be originate by the measuring the local statistics of the image between two dates. The local statistics is found by using a cumulate-based series expansion, which determines probability density functions in the neighbourhood of each pixel in the image. The change detection of the SAR images can also be done by the help of another technique called hybrid conditional random field (HCRF) model [9]. This is an advanced technique used nowadays. In this method we construct the statistics of the log-ratio image which has been derived from the two-temporal SAR images into conditional random field model. In this we use the Gamma distribution (GΓD) for finding the log-ratio value [19]. This had its own restrictions so it is not broadly used. Another method that was introduced is DWT Based Image Fusion & RFLICM Clustering [10]. In this we use the clustering technique called RFLICM. The main gain of this method is that it can be used for the noise removal and speckle noise can be removed is an effective way.

3.METHODOLOGY

As said before in the overview we primarily develop a speckle reduction algorithm by the wavelet denoising technique. Then we find the DI of the SAR images by the help of the image fusion of the mean-ratio image and log-ratio image. After this we analyse the DI that is been obtained. Later we cluster the changed and unchanged region by the help of the FCM along with the improved MRF energy function.

3.1. Wavelet Denoising technique for advanced speckle noise removal

We have already seen that the rate of speckle noise in the SAR images is very high as it is independent of sunlight and other atmospheric situations. So initially we remove the speckle noise that is present in the original SAR images. This is a Threshold Technique for speckle noise removal. Here we use the 4D band, because low band gives most precising value.Image is taken as signal which is the combination of sine and cosine values. So first we create a filter band to apply on LL.We do Discrete Wavelet Transform (DWT), by taking discrete value for alpha and we create a filter band. The value in filter band is used as threshold. Denoising based on thresholding in the wavelet domain is initially proposed.Thresholding typically involves a binary decision. The corresponding handling of wavelet coefficients usually consists of either "keeping" or "killing" the value of the coefficient. As we know there are two thresholding methods, namely soft and hard thresholding. For each wavelet coefficient, if its amplitude is smaller than a predefined threshold, it will be set to zero (kill); otherwise it will be kept unchanged (hard thresholding), or shrunk in the absolute value by an amount of the threshold (soft thresholding). The key decision in the thresholding technique is the selection of an appropriate threshold. If this value is too small, the recovered image will remain noisy. Now by the help of inverse discrete wavelet transform we combine the low band with the high band and produce a speckle noise reduced image.

3.2. Generation of Difference Image (DI)

In this paper we introduce a novel method to find the difference image of the two SAR images. In this image fusion technique is introduced to generate a difference image by using complementary information from a mean-ratio image and a log-ratio image.We take the use of both the mean ratio method and log ratio method so as to get the information of both changed and unchanged region. Both the method is more robust and non-sensitive to speckle noise.

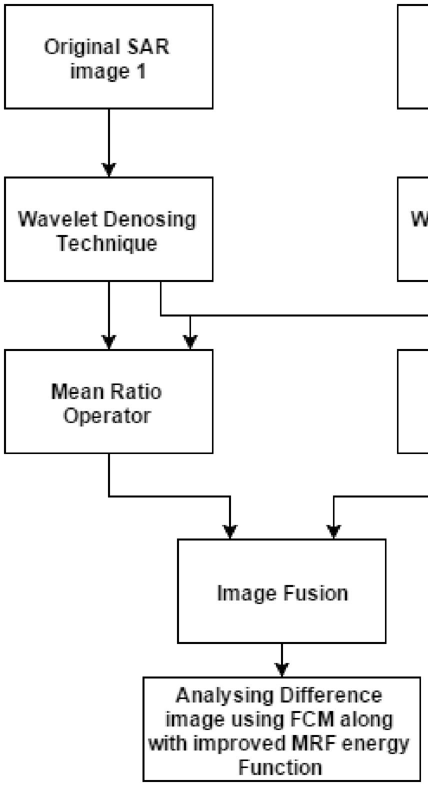

Fig 1. Flowchart of the proposed change detection approach.

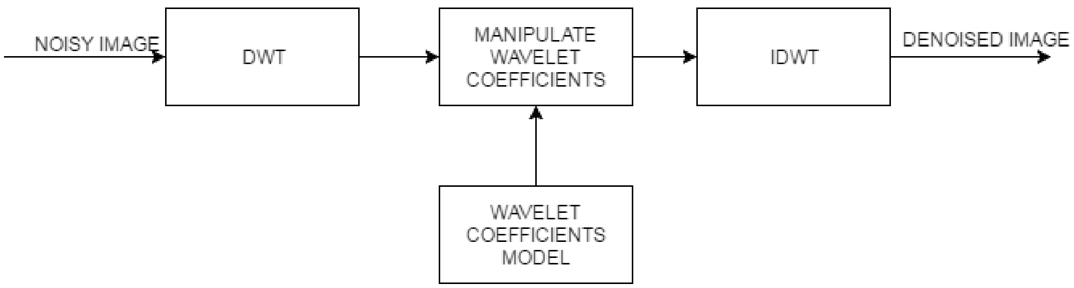

Fig. 2. The wavelet denoising procedure.

The basic strategy behindtaking the log ratio and mean ratio operator is that log ratio operator can work well with low frequency sub band and can reduce speckle noise. But the mean ratio operator works well with all the sub bands but is not efficient in speckle noise removal. So we do the fusion of both the two methods to get find the difference image.

The image fusion structure based on the wavelet transform can be styled as follows: First, we find the DWT of each of the two source images and obtain the multi resolution decomposition of each source image.Now we find the mean ratio image and log ratio image from the decomposed images i.e., Xm and Xl respectively which is given as,

$$X_m = 1 - \min\left(\frac{\mu_1}{\mu_2}, \frac{\mu_2}{\mu_1}\right)$$

$$X_l = \left|\log\frac{X_2}{X_1}\right| = |\log X_2 - log\, X_1|$$

In particular, the wavelet coefficients are fused using different fusion rules for a low-frequency band and a high-frequency band, respectively.

$$D_{LL}^F = \frac{D_{LL}^m + D_{LL}^l}{2}$$

$$D_\varepsilon^F = \begin{cases} D_\varepsilon^m(i,j), & E_\varepsilon^m(i,j) < E_\varepsilon^l(i,j) \\ D_\varepsilon^l(i,j), & E_\varepsilon^m(i,j) \geq E_\varepsilon^l(i,j) \end{cases}$$

For high frequency we use energy function.

$$E_\varepsilon(i,j) = \sum_{k\epsilon N_{i,j}} [D_\varepsilon\,(k)]^2$$

Finally, the inverse DWT is applied to the fused multi resolution representation to obtain the fused result image.

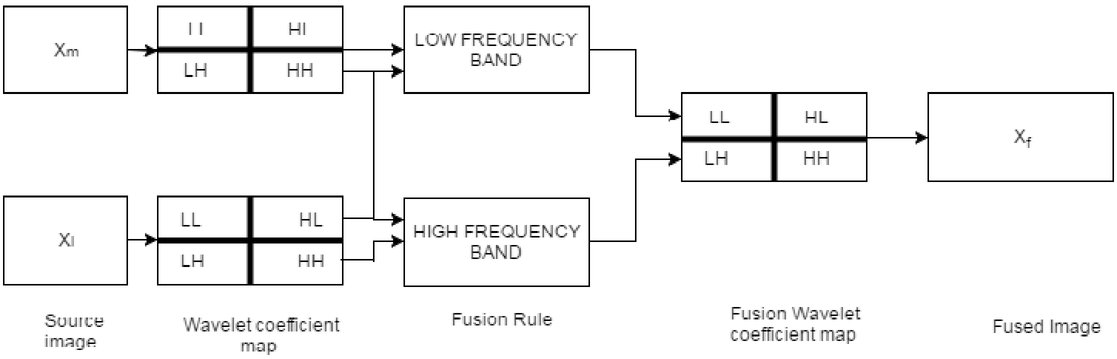

Fig.3. Process of image fusion based on the DWT.

3.3. Notions involved in the practise of FCM

By the help of the image fusion we are able to differentiate between the changed and unchanged image areas. This basically deals with the image segmentation process. Clustering is the process of dividing data elements into classes or clusters so that items in the same class are as similar as promising, and items in different classes are as dissimilar as possible. Usually in clustering each node is clustered into a single class but in FCM each node can be clustered to more than one class. The practise of FCM helps to cluster these images. FCM is a well-known and popular clustering method used nowadays.

The FCM algorithm attempts to partition a finite collection of n elements X= {x1... xn} into a gathering of c fuzzy clusters with respect to some given criterion. Given a finite set of data, the algorithm [15] returns a list of $\mathbb{C}$ cluster centers C= {c1,…,cn}. Here the algorithm works based on the degree of membership function, i.e. let S be a set and s a member of that set, A fuzzy subset F of S is denoted by a membership function mF(s) thatmeasures the 'degree' to which s belongs to F.Fuzzy c-means has been used widely as a very central tool for image processing in clustering objects in an image.

In order to decrease the effect of speckle noise, we propose a unique form of the energy function of the improved MRF to modify the membership of the FCM algorithm instead of altering the objective function. Therefore, the MRF can be utilized to consider the spatial context and, thus, to enhance the traditional FCM algorithm without creating much time complexity. We can test the complexity so as to obtain enhanced results. Here using the improved MRF function help to reduce the speckle noise present in the image dataset.

3.4. Brief explanation of the procedure of Markov Random Field Fuzzy C Means

In the 1st iteration we use the FCM algorithm and find the membership matrix. By the help of Kullback Leibler divergence we find the Standard Deviation (SD) and mean. In the K^{th} iteration, we find the energy function,

$$E_{ij} = -\ln\left(mu_{ij}\right)$$

$$mu_{ij} = \underset{m\in\partial_j}{\mathrm{mean}}\{u_{im}\}$$

Next Using Gibbs expression,we find the probability matrix,

$$\pi_{ij}^{k} = \frac{\exp\left(-E_{ij}^{k}\right)}{\exp\left(-E_{u|j}^{k}\right) + \exp\left(-E_{cj}^{k}\right)}$$

Compute the conditional probability and then generate the distance matrix,

$$p_i^k\left(y_j \middle| \mu_i^k, \sigma_i^k\right) = \frac{1}{\sigma_i^k\sqrt{2\pi}} \exp\left[-\frac{\left(y_j - \mu_i^k\right)^2}{2\left(\sigma_i^k\right)^2}\right]$$

$$d_{ij}^k = -\ln\left[p_i^k\left(y_j \middle| \mu_i^k, \sigma_i^k\right)\right]$$

Compute the objective function j,

$$J_{ij}^k = \sum_{i=u,c} \sum_{j\in I_X} (u_{ij}^k)^2\, (d_{ij}^k)^2$$

$$\left|J_{ij}^k - J_{ij}^{k-1}\right| \leq \delta$$

In case of convergence shown above, where δ is the convergence threshold, exit and output; otherwise update the membership function, mean and standard deviation,

$$u_{ij}^{k+1} = \frac{\pi_{ij}^{k} \exp\left(-d_{ij}^{k}\right)}{\pi_{uj}^{k}\, exp\left(-d_{uj}^{k}\right) + \pi_{cj}^{k}\, exp\left(-d_{cj}^{k}\right)}$$

$$\begin{cases} \mu_i^{k+1} = \dfrac{\sum_{j\epsilon I_X}\left(u_{ij}^{k} y_j\right)}{\sum_{j\epsilon I_X}\left(u_{ij}^{k}\right)} \\ \sigma_i^{k+1} = \sqrt{\dfrac{\sum_{j\epsilon I_X}\left[u_{ij}^{k}\left(y_j - \mu_i^{k+1}\right)^2\right]}{\sum_{j\epsilon I_X}\left(u_{ij}^{k}\right)}} \end{cases}$$

The total review of the methods used in the change detection of the SAR images help in the effective detection of the changes in the SAR images taken in same place at different time [fig 1]. Here we start the help of the Wavelet Bayesian denoising method for finding the speckle noise in the image and for the actual removal of the noise in the SAR images, then we find the difference image of the SAR images by the image fusion of Mean Ratio image and Log ratio image. Later we move to the FCM clustering along with improved MRF energy function. The main Dataset used in this project are Bern dataset, Ottawa dataset and Yellow River dataset.

4. CONCLUSION

In this paper we reveal the difference in the synthetic aperture radar (SAR) images by the aid of Fuzzy c-means (FCM) clustering alongside with the help of improved Markov random field (MRF) as an energy function. Initially, we apply a Wavelet Denoising technique to reduce the speckle noise that is present in the SAR images. Then we generate the difference image (DI) with the help of the log-ratio operator and mean-ratio operator and then analyse the DI. Later we add the improved MRF procedure into the FCM and find the change in the images. Here we mainly concentrate in the synthetic radar images (SAR).

In this paper we use mainly 3 dataset, i.e. Bern dataset, Ottawa dataset and yellow river dataset. The method is widely used and has got many advantages. The main advantage of this method is that it can be used to reduce the speckle noise and the technique is computationally simpler.

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